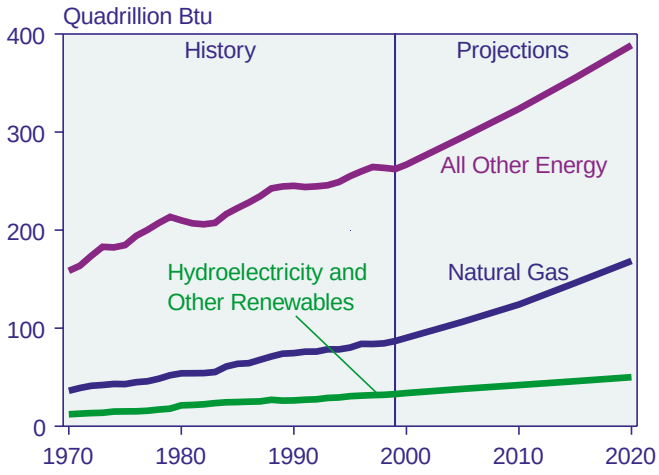
Hydroelectricity and Other Renewable Resources

The renewable energy share of total world energy consumption is expected to decline slightly, from 9 percent in 1999 to 8 percent in 2020, despite a projected 53-percent increase in consumption of hydroelectricity and other renewable resources.

Although fossil fuel prices reached 10-year highs in 2000, the *IEO2001* reference case projection expects energy prices over the long term to remain relatively low, constraining the expansion of hydroelectricity and other renewable resources over the projection period. Worldwide, renewable energy use is expected to increase by 53 percent between 1999 and 2020, but the current 9-percent share of renewables in total energy consumption is projected to decline slightly, to 8 percent in 2020 (Figure 68). Total renewable energy use is projected to rise from 33 quadrillion Btu in 1999 to 50 quadrillion Btu in 2020 (see Appendix A, Table A8).

Much of the growth in renewable energy use in the *IEO2001* reference case is attributable to large-scale hydroelectric projects in the developing world, particularly in developing Asia, where China and India, as well as other developing Asian nations such as Nepal and Malaysia, are already building or planning to build hydroelectric projects that exceed 1,000 megawatts. Hydroelectricity and other renewable energy consumption is expected to grow by 4.0 percent per year in developing Asia over the projection period, with particularly strong growth projected for China (Figure 69).

Figure 68. World Consumption of Renewable Energy, Natural Gas, and Other Energy, 1970-2020

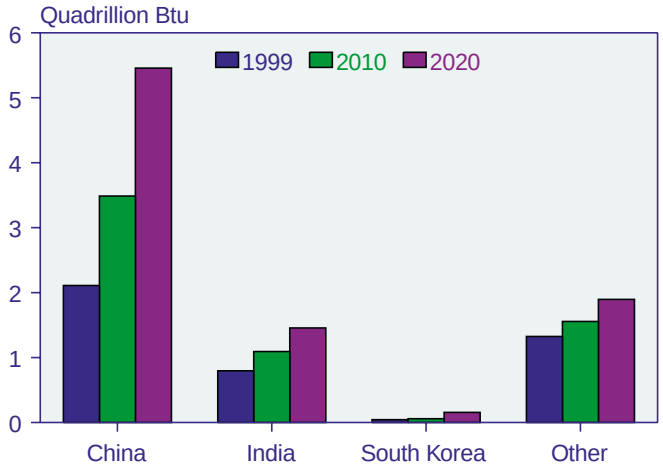


Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Several large-scale hydropower projects were revived or moved forward in 2000 in developing Asia. Construction of the 18,200-megawatt Three Gorges Dam project in China continued despite charges of corruption that surfaced in 2000, including a charge of embezzlement of $1.4 million by an official who was subsequently found guilty and sentenced to death [***1***]. In India, the Supreme Court ruled that construction of the 1,450-megawatt Sadar Sarovar hydroelectric project could continue after being stalled by lawsuits for more than 6 years. In Malaysia, the government announced that it was considering increasing the capacity of its Bakun hydroelectric project from 500 megawatts to 2,500 megawatts, the scale of the original plans for Bakun. Laos signed a Memorandum of Understanding with Thailand for a 25-year power purchase agreement to take electricity from the proposed 920-megawatt Nam Theun 2 project [***2***].

Among the countries of the industrialized world, wind-powered electricity is still enjoying robust growth. Several States in the United States have adopted renewable portfolio standards (RPS) that should help promote strong growth of wind power. Australia is also poised to enact legislation that will act as an RPS, and the country is already seeing a jump in the plans to install wind

Figure 69. Renewable Energy Consumption in Developing Asia, 1999, 2010, and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2010 and 2020:** EIA, World Energy Projection System (2001).

power, in excess of 1,000 megawatts [***3***]. Several countries in Western Europe continue strong development of wind power, including Germany, Denmark, and Spain. In the first 9 months of 2000 alone, 987 megawatts of wind capacity were installed in Germany, bringing the country's total wind capacity to 5,432 megawatts, twice that of the United States [***4***].

Renewable energy in Western Europe has been encouraged by a number of government policies and subsidies aimed at increasing the penetration of alternative energy sources. In 2000, the European Union (EU) Secretaries of Energy announced a cooperative position on renewables. By 2010, the EU expects renewable energy sources to contribute 22 percent of all power production among the member countries [***5***]. There are already policies in place in Germany, Denmark, and the United Kingdom to subsidize the use of renewable energy sources.

The *IEO2001* projections for hydroelectricity and other renewable energy sources include only on-grid renewables. Although noncommercial fuels from plant and animal sources are an important source of energy, particularly in the developing world, comprehensive data on the use of noncommercial fuels are not available and, as a result, cannot be included in the projections. Moreover, dispersed renewables (renewable energy consumed on the site of its production, such as solar panels used to heat water) are not included in the projections because there are also few comprehensive sources of international data on their use.

Regional Activity

North America

Hydroelectricity remains the most widely used form of renewable energy in North America, particularly in the United States and Canada. North America has a total of 175 million kilowatts of installed hydroelectric capacity, compared with installed capacity of 19 million kilowatts for other renewable energy sources (i.e., geothermal, wind, solar, and biomass). While Canada still has several projects planned or under construction for further expanding its hydroelectric resource base, hydropower generation in the United States is, overall, expected to decline—both because most of the best sites for hydro development have already been exploited and because of the recent emphasis on the adverse impact that large-scale hydroelectric facilities may have on the environment. In Mexico, there are few plans to expand the use of renewable energy resources beyond off-grid, small facilities in rural areas that are far from the national electricity grid. *IEO2001* projects that North America's renewable energy use will increase by 1.3 percent per year, from 11.1 quadrillion Btu in 1999 to 14.5 quadrillion Btu in 2020 (Figure 70).

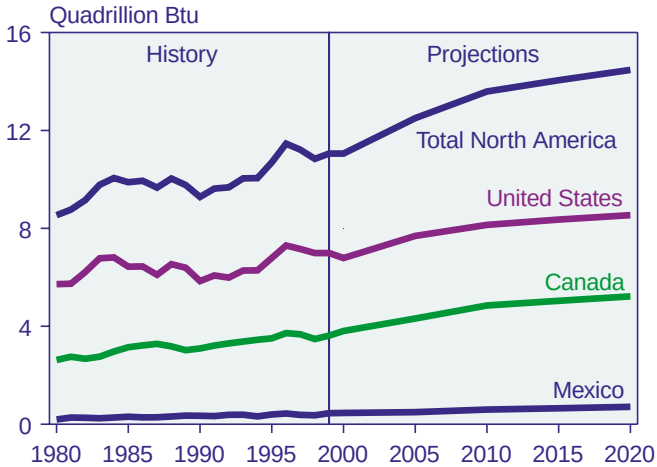
United States

Potential sites for hydroelectric power have already been largely established in the United States and environmental concerns are expected to prevent the development of any new sites in the future. The Energy Information Administration's *Annual Energy Outlook 2001* projects that conventional hydroelectric generation will decline from 389 billion kilowatthours in 1999 to 298 billion kilowatthours in 2020 as increasing environmental and other competing needs reduce the productivity of generation from existing hydroelectric capacity [***6***]. On the other hand, growth in U.S. electricity generation from other renewable energy sources (geothermal, biomass, landfill gas, and wind) is projected over the forecast horizon, from 77 billion kilowatthours in 1999 to 146 billion kilowatthours in 2020. Biomass is projected to enjoy the largest increase among renewable energy sources, rising by 80 percent and reaching 65.7 billion kilowatthours in 2020.

Ten States (Arizona, Connecticut, Maine, Massachusetts, Nevada, New Jersey, New Mexico, Pennsylvania, Texas, and Wisconsin) have introduced RPS programs, as well as other requirements to construct new renewable-powered capacity. The RPS programs vary substantially, but all require that the State's renewable share of total electricity be increased by using a range of eligible renewable sources. Much of the expected growth in renewable energy in the United States is attributed to these programs.

Texas and New Jersey account for the largest amount of new renewable electricity generating capacity expected to result from RPS programs over the forecast horizon.

Figure 70. Renewable Energy Consumption in North America, 1980-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

The Texas RPS requires that 2,000 megawatts of new renewable energy generating capacity be constructed in Texas by 2009, with increasing interim requirements and individual utilities' shares assigned in proportion to their retail sales. The utilities may either generate the renewable electricity themselves or purchase credits from other generators with surplus renewable electricity supplies. Wind and landfill gas are expected to provide most of the renewable energy under the Texas RPS, but the selection of possible sources of renewable energy for the Texas plan also includes biomass, geothermal, hydroelectricity, and solar energy technologies. Several large wind facilities have already been announced or contracted since the program was announced.

Under New Jersey's RPS program, sales of renewable-generated electricity must increase until 6.5 percent of each of the State's retail electricity providers' sales are supplied by renewables by 2012 [***7***]. Any electricity provider falling below the renewable requirement would be required either to make it up in the next year or to purchase credits from another electricity provider with a surplus of renewable-generated electricity. There is also a provision for generating units outside New Jersey to contribute to the renewable share. Biomass and landfill gas projects are expected to account for the largest number of new renewable projects, along with some new wind power projects.

Although California does not have an RPS program, the State has enacted a renewable energy mandate with a funding requirement under California Assembly Bill 1890 (A.B. 1890). Under A.B. 1890, $162 million is to be collected from the ratepayers of investor-owned utilities. Renewable energy projects are proposed on a voluntary basis and bid for support on a per-kilowatthour incentive basis. A.B. 1890 projects are expected to include primarily wind, geothermal, and landfill gas. Although details have not yet been made available, the A.B. 1890 mandate was extended in August 2000 with additional funding.

Wind power in the United States enjoyed substantial growth in 1999, mostly because of the threatened expiration of the Federal tax credit for wind production in June 1999 (which has since been extended to the end of 2001). Between 1998 and 1999, installed wind capacity grew from 1,890 megawatts to 2,455 megawatts, with the greatest rate of construction occurring during the period from July 1998 to July 1999 [***8***], when a record 1,014 megawatts of new wind installations came on line, including 841 megawatts of new generating capacity and 173 megawatts of repowering projects (where new turbines replaced older, less efficient units, mostly in California).

New wind power projects were constructed mainly in the country's Midwest. In 1999, new wind facilities were installed in Alaska, California, Colorado, Iowa, Kansas, Maine, Minnesota, Nebraska, New Mexico, Pennsylvania, Texas, Wisconsin, and Wyoming, and wind power is now being generated in 22 States (Figure 71). In September 1999, the world's largest wind farm was dedicated near Storm Lake, Iowa. The farm, operated and owned by Enron Wind Corporation, is composed of 257 turbines with a combined capacity of 193 megawatts and will generate enough electricity for 71,000 U.S. homes [***9***]. In September 2000, New York completed the largest wind project on the East Coast, the 11.5-megawatt Madison County project near Hamilton [***10***].

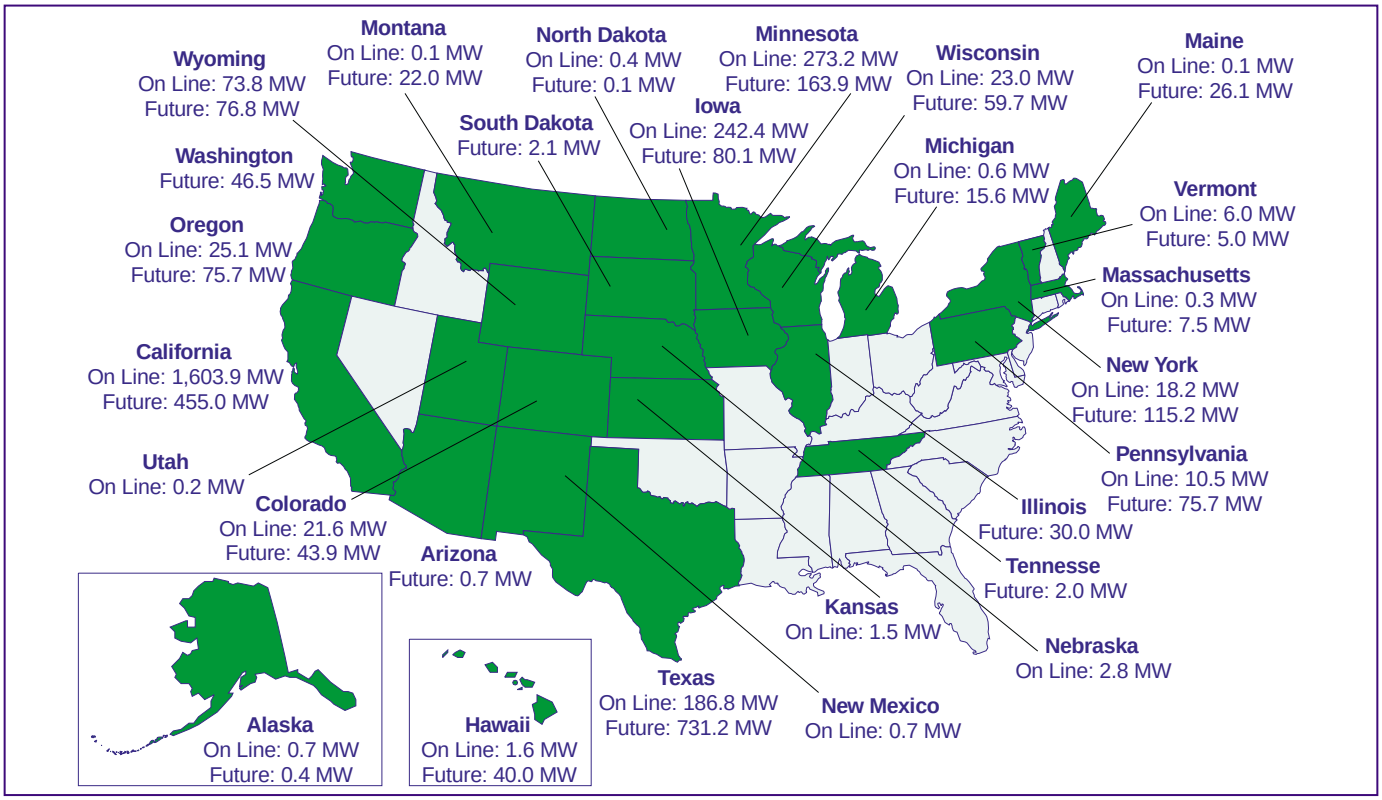
Canada

Canada has also begun modest development of its wind resources. In June, wind turbine manufacturer Vision Quest installed the largest turbines to date and connected them to the Alberta provincial grid [***11***]. The turbines, 154 feet in diameter and 164 feet high, have a peak capacity of 660 kilowatts. One is located near Pincher Creek and one near Hill Spring, both in Alberta. In December 2000, Vision Quest commissioned a 10.5-megawatt, 16-turbine wind farm at Castle River, also in Alberta province [***12***]. At present, Vision Quest has 7 wind power plants operating and 13 under construction.

In addition, the Canadian government announced that it would invest up to $329 million between 2000 and 2005 to reduce greenhouse gas emissions, with a commitment to purchase 20 percent of the government's electricity supplies from nonhydroelectric renewable resources [***13***]. To that end, the government has pledged that, by 2002, half of the average 25,000 megawatts of electric power used annually by government-owned and operated facilities in Saskatchewan will be supplied by wind. To accomplish this, the Canadian government will contribute $8.16 million over a 10-year period to Saskatchewan's electric utility, SaskPower, for the purpose of developing "green power" in the province. At present, the government is trying to negotiate a similar arrangement for Prince Edward's Island.

Canada has plans to continue developing hydroelectric sites, but for the most part the plans do not include large-scale projects that often lead to contention between developers and native populations and criticisms about their potential adverse environmental impact. Moreover, hydropower developers are trying to work more closely with native peoples to make it easier to begin construction on new projects. Hydro Quebec struck an arrangement with the Grand Council of the Crees that will allow the tribe to conduct a 3-month study of the utility's plan to develop one of the few remaining large-scale projects, the 1,280-megawatt Rupert-Eastmain Hydroelectric Project, in northern Quebec [***14***]. The utility has agreed to pay the Cree $302,800 to study the economic, commercial, and

Figure 71. Grid-Connected Wind Power Plants in the United States as of November 2000



Source: American Wind Energy Association, "Wind Project Database: Wind Energy Projects Throughout the United States," web site www.awea.org (November 15, 2000).

environmental impacts of the proposed dam. Hydro Quebec has additionally offered the Cree an opportunity to invest and become co-owners in the Rupert-Eastmain Project which would cost between $1.7 and $2.0 billion to construct and would generate revenues between $101 and $121 million each year. The project would be built on the Eastmain River (north of Nemaska) and would require diverting 90 percent of the Rupert River's flow into a planned 240-square-mile reservoir.

Similar to the Hydro Quebec/Cree agreement, Manitoba Hydro and the Tataskweyak Cree Nation reached an agreement that will give the Tataskweyak Cree partial ownership in the proposed 560-megawatt Gull Rapids hydroelectric project [***15***]. According to the agreement, the Tataskweyak Cree would be able to purchase up to 25 percent ownership in the $871 million Gull Rapids Project and would receive 25 percent of all revenues produced by the project. Gull Rapids is slated for completion in 2008. It will be located on the Nelson River near Split Lake. Manitoba Hydro also is considering development of the 150-megawatt Notigi and 250-megawatt Wuskwatim projects on the Burntwood River.

Several additional hydroelectric projects are expected to be developed in Canada. Brascan Corporation plans to construct the 90-megawatt High Falls Power Project on the Michipicoten River near Wawa in northern Ontario, Canada [***16***]. The project will cost an estimated $50 million to construct. No schedule for construction has been released. The Churchill River Project in Newfoundland Province is also being planned. Originally slated to be a 2,264-megawatt project to be jointly developed with Quebec, plans for the project have been progressively scaled back over the past several years [***17***]. The original project had been criticized because of the impact that diverting the Romaine River would have on the environment and aboriginal families living in the area. Moreover, Quebec and Newfoundland officials have noted that the changing U.S. energy market made it difficult to negotiate export prices for the power. At the end of 2000, the government of Newfoundland announced that the size of the project (now to be called the Lower Churchill Power Project) had been reduced to a 1,700-megawatt powerhouse and would not require water from Quebec to complete. Construction on Lower Churchill will not begin before 2004 and should take 4 years to complete.

Mexico

Renewable energy sources remain only a small part of the energy mix in Mexico. Hydroelectricity and other renewables accounted for only 7 percent of Mexico's total energy consumption in 1999 [***18***]. The *IEO2001* reference case projects that consumption of energy from renewable sources in Mexico will increase by 2.2 percent

per year, from 0.4 quadrillion Btu in 1999 to 0.7 quadrillion Btu in 2020. Renewables are expected to lose share of total energy consumption in Mexico, falling from 7 percent in 1999 to 6 percent by 2020, as a result of strong growth in oil use (3.7 percent per year).

There are few official programs aimed at increasing the amount of renewable energy used in Mexico. Concerns about pollution and greenhouse gas emissions have largely been addressed, so far, by introducing natural-gas-fired electricity generation. Nevertheless, wind power developers have estimated that Mexico's wind resources are plentiful enough that some 3,000 to 5,000 megawatts of wind capacity could be achieved, particularly in the Tehuantepec Isthmus, in the southern part of the country [***19***]. By the end of 1998, however, only 3.0 megawatts of wind capacity had been installed, and no wind capacity was added in 1999. Development of a 54-megawatt wind farm proposed in 1996 by Mexico's Federal Electricity Commission was postponed in 1999, and five other projects proposed by private companies are under negotiation. Prospects for construction appear dim; construction was postponed for all five in 1999, despite the fact that building permits have already been issued for four of them.

Western Europe

With most of the hydroelectric sites in this region already established, wind power continues to enjoy the greatest rates of growth in Western Europe. Germany, Denmark, and Spain have the fastest-growing markets for wind power in the region, and Greece, France, Belgium, and Italy, among others, have also had some success in installing wind power. Total consumption of hydroelectricity and other renewable resources in Western Europe is projected to grow by 1.8 percent per year in the *IEO2001* forecast, from 5.6 quadrillion Btu in 1999 to 8.2 quadrillion Btu in 2020 (Figure 72).

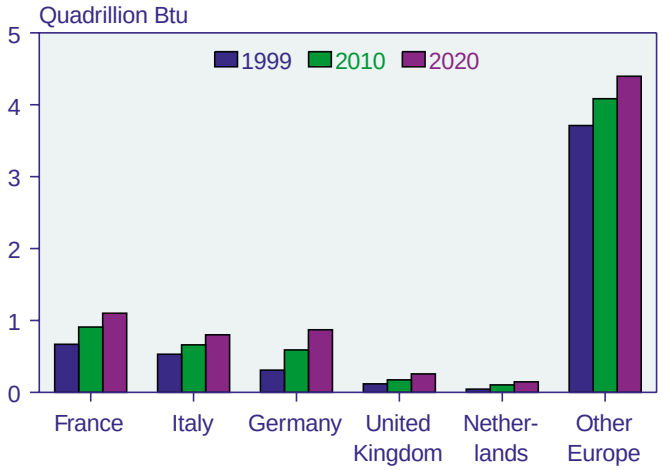
Many European governments have been attempting to increase the role of renewable energy sources through subsidies and other incentive programs in efforts to reduce emissions of carbon dioxide and other pollutants. Most of the countries in the EU assess energy taxes to keep consumer energy use in check. In Denmark, electric utilities are assigned carbon dioxide quotas, and they pay a fine of 40 Danish Krone (about $5 U.S.) for every metric ton of carbon dioxide emitted over their quota.

Germany's wind power program has been particularly successful. The country has been among the world's leaders in installing new wind capacity over the past several years. In the first 9 months of 2000 alone, 987 megawatts of wind capacity were installed in Germany, bringing the country's total wind capacity to 5,432 megawatts, more than twice the installed wind generation capacity of the United States [***20***].

In 1991, Germany enacted its Electricity Feed Law (EFL), which fixes "buy-back" prices for approved renewables at 90 percent of the average private consumer tariff. In February 2000, the government announced passage of a new law to replace the EFL, the Gesetz für den Vorrang Erneuerbarer Energien. The new law will fix tariffs for approved renewable energy projects for a 20-year period dating from the plant commissioning and will apply incremental annual price cuts [***21***]. Initial prices were set at 47.7 cents per kilowatthour for solar, 8.6 cents per kilowatthour for wind, from 9.6 to 8.2 cents per kilowatthour for biomass (depending on the amount of electricity generated), 8.4 to 6.7 cents per kilowatthour for geothermal, and 7.2 to 6.3 cents per kilowatthour for hydropower, waste, and sewage gas.

The German price scheme requires that solar energy prices be reduced by 5 percent per year from the current level of 47.7 cents per kilowatthour. Biomass prices will fall by 1 percent per year beginning in 2002. As for wind, after the first 5 years of operation, German wind tariffs will drop to 5.8 cents per kilowatthour for turbines that have generated 150 percent more power than a defined "standard turbine" limit [***22***].[17] For those turbines that do not attain the 150 percent limit, the maximum payment is to be extended by 2 months for every 0.75 percentage points for which production is below the limit.

Figure 72. Renewable Energy Consumption in Western Europe, 1999, 2010, and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2010 and 2020:** EIA, World Energy Projection System (2001).

[17]The defined "standard turbine" or "reference turbine" is actually a series of turbine types operating at an average wind speed of 5.5 meters per second at 30 meters height with logarithmic height profile and a roughness length of 0.1 meters in specific conditions averaged over a period of 5 years using an internationally recognized and EU-approved power curve model.

For offshore wind plants that are more than 3 miles from land and come on line by 2006, a 9-year tariff of 8.6 cents per kilowatthour will be applied.

Spain has made remarkable gains in wind energy over the past several years. Installed wind capacity has grown from 73 megawatts in 1994 to 1,539 megawatts in 1999 [***23***]. In 1999, Spain was third after Germany and the United States in new installed capacity, adding 705 megawatts (Germany added 1,568 megawatts, the United States 841 megawatts). Moreover, there are already plans to install another 10,800 megawatts of wind capacity between 2000 and 2012.

To encourage the penetration of renewable energy sources, the Spanish government enacted Royal Law 2818 in December 1998, establishing a pricing regime for renewable energy plants that are connected to the national grid [***24***]. The regime allows producers to choose either a fixed price per kilowatthour generated or a variable price calculated from the average price of the market pool, plus a bonus for every kilowatthour produced. The Spanish Ministry of Energy and Industry is to update the prices every year according to the annual variation in electricity market prices. Renewable energy sources allowed under this program are small hydroelectric, wind, geothermal, wave, and primary and secondary biomass.[18] In 2000, fixed prices ranged from 5.1 to 5.5 cents per kilowatthour, and bonuses ranged from 2.2 to 2.6 cents per kilowatthour according to energy type (Table 19).

Greece made substantial additions to its wind capacity in 1999. The country more than doubled total installed capacity, adding 67.5 megawatts at nine wind projects and bringing the total installed wind capacity operating in Greece to 107 megawatts at the end of 1999 [***25***]. Greece's Ministry for Development has set a target of 350 megawatts of installed wind capacity by 2005. To achieve that aim, two government programs have been established to encourage wind installation. The Law for the Economic Development (Law 2601/98) affords wind projects a 40-percent subsidy for the cost of installation. The Operational Program for Energy-Renewables within the Community Support Framework also offered subsidies for renewable energy projects installed between 1994 and 1999.

Wind projects made some inroads in several other Western European countries in the past year. In Belgium, state utility Electrabel announced that it had signed a contract for the construction of a 100-megawatt offshore wind plant. Construction on the project, which will be the largest of its kind in Europe, is expected to begin as soon as an environmental assessment is completed. It is scheduled for completion by 2004 [***26***]. A second phase of the project aims to increase the total installed capacity to 400 megawatts.

Installation of one of the world's largest wind farms was completed in Italy in June 2000. The 170-megawatt project is located in the southern part of the country, in Campania and Puglia, near Naples. Japan's Tomen Corporation installed the wind farm at a cost of about $260 million. Electricity generated at the project will be sold to Italy's state-owned utility, Enel SpA [***27***].

There are some efforts to improve the development of wind power in France. In 1996, France's Electricite de France announced plans to implement a program to increase the amount of wind-generated electricity in the country [***28***]. The purpose of the EOLE 2005 wind program is to install between 250 and 500 megawatts of wind capacity by 2005. In October 1999, Electricite de France stated that 21 wind projects had been selected for development under the program, totaling some 200 megawatts of capacity, and another 5 projects (representing 70 megawatts of wind capacity) were under consideration [***29***].

In 2000, the United Kingdom ended the country's Non-Fossil Fuel Obligation (NFFO) tax that had been used in the past to subsidize nuclear generation (mostly) and renewable energy projects. The NFFO is to be replaced by the Renewable Energy Obligation (REO) [***30***]. The UK government announced that it had set a target to provide 10 percent of the country's electricity supply with renewable energy sources by 2010. The UK Department of Trade and Industry expects that nearly

Table 19. Price Values Under Two Incentive Programs for Renewable Energy Sources in Spain
(1999 Cents per Kilowatthour)

Renewable Energy Source	Bonus Added to the Base Price	Fixed Price
Small Hydropower	2.47	5.37
Wind Plants	2.47	5.37
Geothermal	2.56	5.46
Wave	2.56	5.46
Primary Biomass[a]	2.37	5.28
Secondary Biomass[a]	2.20	5.10

[a]Primary biomass is defined as agricultural crops grown specifically for use in biomass energy production. Secondary biomass is defined as agricultural and forest residues.

Source: International Energy Agency and the National Renewable Energy Laboratory, *IEA Wind Annual Report 1999* (Golden, CO, May 2000), p. 131.

[18]Primary biomass is defined as agricultural crops grown specifically for use in biomass energy production. Secondary biomass is defined as agricultural and forest residues.

one-half of the anticipated target will be met with wind power. The REO is scheduled to begin in October 2001 and will not expire until 2025 [***31***]. The program requires all licensed electricity suppliers to provide a specific proportion of their electricity supplies using renewable energy. Any additional costs incurred by the supplier that are associated with procuring the renewable energy source may be passed on to the consumer, but a "buyout" price has been established should the cost of generating electricity from renewable energy sources prove prohibitive.

The wind industry has had a difficult time in the United Kingdom. While the NFFO (and its related obligations in Scotland and Ireland) have contracted wind energy projects totaling some 2,676 megawatts between 1990 and 1999, only 344 megawatts of capacity were actually built and are operating [***32***]. Only 19 megawatts of new wind capacity were commissioned in 1999. The disappointing rate of completion is a result of problems with obtaining planning consent. Almost all the wind power projects submitted for planning approval in 1998 failed to secure it. Several projects did receive approval in 2000, including 4 megawatts in Hare Hill, County Durham, and 2 megawatts off the coast of Northumberland in the North Sea—the United Kingdom's first offshore wind farm [***33***]. Further, construction was completed on the 6.5-megawatt Lambrigg Wind Farm in Cumbria, England, the largest wind farm constructed in England since 1993 [***34***]. Construction also began in June 2000 on the first large wind turbine ever to be built in Ireland. The turbine is to be located in Dungannon District; no schedule for completion has been released [***35***].

Industrialized Asia

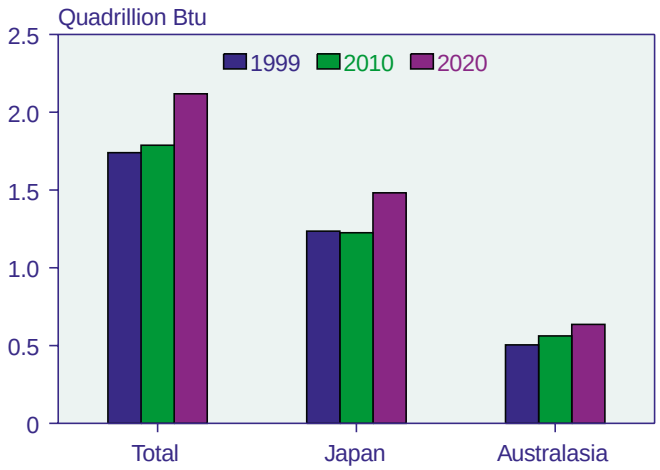
The countries of industrialized Asia (Australia, Japan, and New Zealand) have markedly different electricity energy mixes. Japan is the only one of the three countries with a nuclear generation program, supplying one-third of its electricity from nuclear power plants. Hydroelectricity and other renewable energy sources supply only 12 percent of the country's electricity. Renewables also account for about 10 percent of Australia's electricity supply, and thermal generation (predominantly coal) accounts for nearly 90 percent. In contrast, renewable energy sources provide 73 percent of New Zealand's electricity supply.

The *IEO2001* reference case projects that hydroelectricity and other renewable sources in Japan will grow by 1.5 percent per year between 1999 and 2020 (Figure 73). In 2000, the Japanese Ministry of International Trade and Industry (MITI) announced plans to encourage the development of renewable resources, proposing a "Green Credit System" under which the government would issue certificates to domestic electricity producers corresponding to the amount of natural energy or recyclable energy they generate [***36***]. Electricity retail companies either would be required to buy directly a specified amount of qualifying renewable-generated electricity or would have to purchase certificates. The certificates would also be tradable between electricity companies under the new system. Ultimately, the cost of purchasing the certificates would be passed on to consumers. Plans are to introduce the scheme by mid-2001.

In 1999, Japan added 43.4 megawatts of wind capacity, increasing its total installed wind capacity by almost 40 percent to 75.1 megawatts [***37***]. Japan has set a national wind energy target to install 300 megawatts of wind capacity by 2010. Many of the existing wind turbines are located around the coast of Hokkaido, Japan's most northerly island, including the country's largest wind farm at Tomamae, with 20 megawatts of installed capacity [***38***]. The development of the Hokkaido wind potential was encouraged by the 1998 decision of Hokkaido Electric Power to pay preferential prices for wind-generated electricity of 2 yen per kilowatthour over the regular price paid for thermal-generated electricity [***39***].

Japan's Marubeni Corporation announced plans to construct a 26-megawatt wind generation facility in Kagoshima Prefecture, with 13 megawatts each installed in Nejime and Sata, the southernmost towns of the southern Japanese island, Kyushu. The project is estimated to be completed in 2002 and will become Japan's largest wind power project [***40***]. Marubeni plans to ask the New Energy and Industrial Technology Development Organization (which is an affiliate of MITI) to subsidize the project.

Figure 73. Renewable Energy Consumption in Industrialized Asia, 1999, 2010, and 2020



Note: Australasia includes Australia, New Zealand, and the U.S. Territories.

Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2010 and 2020:** EIA, World Energy Projection System (2001).

Australia has also been slow to develop nonhydroelectric renewable energy sources. At the end of 1999, the country had installed only 10 megawatts of wind capacity [***41***]. In 1999, however, the government established a Ministerial Council on Greenhouse Gas Abatement which, in turn, set a mandatory target for electricity retailers and large purchasers to acquire 2 percent of their electricity from renewable energy sources by 2010. The Council expects the legislation to be enacted in 2001 and, because of the rich wind resources available in Australia, to spur growth in the Australian wind industry. There are indications that the wind industry is already responding to the potential legislation, with more than 500 megawatts of wind power either being planned or under construction in Australia at the end of 2000 [***42***].

Several wind projects commenced in Australia in 1999, and wind farms are being developed in Queensland, New South Wales, Tasmania, and Western Australia. The 10-megawatt wind project at Blayney in the central part of the state—the largest in New South Wales—went into operation in October 2000 [***43***]. In Western Australia, the government announced plans to construct a 22-megawatt, $45 million wind farm in Albany, near the southwest coast [***44***]. It is scheduled to be completed in July 2001 and will be the largest wind plant in operation in Australia. The government estimates that the project will be able to provide 75 percent of the electric power needed in Albany. Construction of an 18.2-megawatt wind farm at Codrington in southwest Victoria is to be completed before the end of 2001. Pacific Hydro has already reached an agreement to sell the power from the project to electricity retailer Powercor and has made plans to develop a similar project in the same region within the next 5 years [***45***]. Hydro Tasmania plans to construct the 130-megawatt Woolnorth wind farm in Tasmania [***46***].

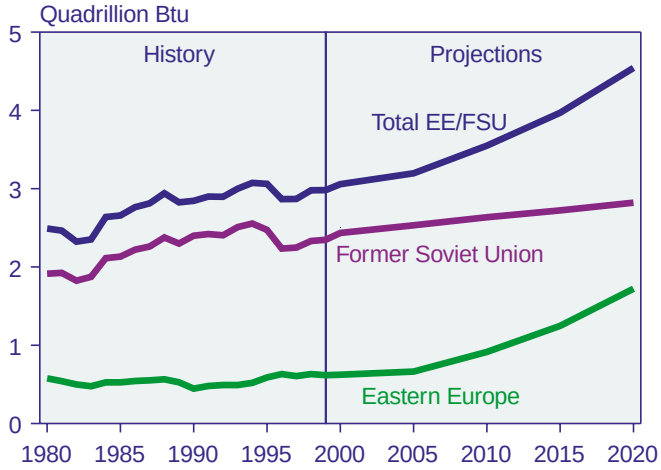
In New Zealand there are few plans to expand the use of renewable resources. The country already relies on hydroelectric power for more than 60 percent of its electricity generation and is concerned about diversifying its electricity fuel mix, because a year of low rainfall could lead to electricity shortages. As a result, most additional generating capacity is expected to be fired by natural gas rather than renewable energy sources. There are only modest proposals to increase the hydroelectric capacity of the country. New Zealand's TrustPower Company has proposed a 62-megawatt hydroelectric project at Dobson, near Greymouth [***47***]. If constructed, it would be the first of its type ever built by the private sector and the first major hydroelectric project started since the Clyde Dam in 1984.

Eastern Europe and the Former Soviet Union

Development of new hydroelectricity and other forms of renewable energy resources is expected to remain fairly low throughout the projection period in Eastern Europe and the former Soviet Union (EE/FSU). Most of the growth is expected to be in expansion and renovation of existing hydroelectric facilities that need repair after difficult economic years. In the countries of the FSU, the economy has only in the past 2 years shown signs of sustained recovery from the collapse of the Soviet Union in the early 1990s. Although the FSU economies are expected to recover over the projection period, it is expected that natural gas, a cheap and plentiful resource in Russia and several other FSU republics, will mainly be used to meet additional energy demand in the future, rather than renewables. Renewable energy use in the EE/FSU region is projected to grow by 2.1 percent per year between 1999 and 2020 in the *IEO2001* reference case, from 3.0 to 4.5 quadrillion Btu (Figure 74).

In Eastern Europe, the economies have recovered much more quickly than those of the FSU; as a result, the prospects for development of hydroelectricity and other renewables are much more optimistic in the *IEO2001* reference case forecast. Renewable energy consumption in Eastern Europe is expected to grow by 5.0 percent per year over the next two decades. As in the FSU republics, much of the growth in energy demand is projected to be met by additional natural gas use, but there are also

Figure 74. Renewable Energy Consumption in Eastern Europe and the Former Soviet Union, 1980-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

opportunities for expanding hydroelectricity in several Eastern European countries, including Bosnia, Slovenia, and Macedonia, where undeveloped potential sites still exist.

In Russia, the FSU's largest economy and electricity consumer, hydroelectricity accounts for about 43,000 megawatts of the country's total installed capacity or about 20 percent of the total [***48***]. Almost three-fourths of Russia's hydroelectric capacity is represented by 11 power stations with more than 1,000 megawatts of capacity, including the 6,400-megawatt Sayano Shushenskoye facility in Khakassia, the 6,000-megawatt Krasnoyarsk facility in Krasnoyarsk province, and the 4,500-megawatt Batsk project in Irkutsk province—three of the four largest power generating facilities in Russia.

Only a few small nonhydroelectric renewable projects have been developed or are planned in Russia. A single 11-megawatt geothermal plant operates in Pauzhetskaya in the Kamchatka region, and there are plans to expand it by 7 megawatts before 2010. Kamchatka has rich geothermal resources, and an estimated 380 to 550 megawatts of potential geothermal capacity could be exploited. A second 80-megawatt geothermal plant is currently under construction in Kamchatka (at Mutnovsk), and the European Bank of Reconstruction and Development (EBRD) has agreed to provide $100 million for the first stage of construction on the project. Total costs are estimated to reach $500 million for the power plant and $120 million for the pipeline.

Hydroelectricity makes up more than 80 percent of Georgia's electricity generation. The country has not yet fully exploited its hydroelectric resources and has an estimated 100 billion kilowatts of potential hydroelectric capacity [***49***]. An Austrian-Georgian coalition of Strabag, Verbundplan GmbH, ABB Kraftwerke AG, and Lameyer International GmbH plans to invest up to $500 million over the next several years for hydroelectric projects. The 250-megawatt Namakhvani and the 100-megawatt Zhoneti projects are planned for construction on the Rioni River, and the 40-megawatt Minadze station is to be constructed on the Kura River. The EBRD also has approved a $39 million loan to refurbish the Inguri Hydroelectric dam, the largest in the country.

In Azerbaijan, several hydroelectric rehabilitation projects are in progress. When completed, these projects should result in an additional 671 megawatts of electricity capacity. The 360-megawatt Mingechaur hydroelectric project on the Kura River is estimated to cost $41 million and is scheduled for completion in 2001. The EBRD loaned the country $21 million to finance the replacement of generators at the plant, as well as to install environmental controls. The Islamic Development Bank and the European Union's Tacis City Twinning program are cosponsoring the effort [***50***]. Plans are also being discussed by state power company Axerenerji for a $42.5 million development of small hydroelectric stations in the autonomous Nakhichevan region [***51***]. The most promising scheme involves construction of a 23.1 megawatt capacity four-station cascade on the Gilan river.

Other proposed projects include a $9.8 million, 4.5-megawatt hydropower station on the Vaykhyr river and an $85 million, 31.5-megawatt plant on the Ordubad River [***52***]. The Islamic Development Bank has expressed interest in assisting with the projects. Azerbaijan had considered potential wind power development for Nakhichevan, but initial studies showed that every wind-generated kilowatthour would cost twice as much as a hydro-generated kilowatthour.

In July 2000, Austria's Small Hydropower Tyrol and Bosnia's Inotrade Sarajevo reached an agreement with the government of Bosnia for a 20-year design, build, operate, and transfer (DBOT) agreement with the Srednjobosanski canton authorities (in central Bosnia) and a purchase power agreement with electric power utility Elektroprivreda Bosne i Hercegovine [***53***]. The consortium plans to invest $6.03 million to construct four hydroelectric projects in central Bosnia. This marks the first investment by a foreign company in Bosnia's power sector. Three of the plants (Prokoska, Jezernica 1, and Mujakovici) are to be located on the Jezernica River. The fourth, the Botun project, is to be installed on the Kozica River. The four run-of-river plants, with a combined capacity of 3.8 megawatts, are expected to begin operating within 2 years.

Bosnia is also still negotiating with the World Bank for a $30 million loan for a project to rehabilitate several thermal and hydroelectric power plants, the so-called "Power 3 Project" [***54***]. Although negotiations have been going on since November 1999, the World Bank believes an agreement will be reached and work on the project could begin in 2001. Eventually, the total value of Power 3 could reach $225 million. In addition to the repairs planned for the electric power plants, there are also plans to improve the region's transmission grid in an effort to improve the transmission of power between southeastern Europe and other European countries by way of Bosnia.

Bulgaria has several plans for upgrading its hydroelectric facilities. Plans to rehabilitate the Gorna Arda facility in southeastern Bulgaria ran into problems in 2000 when Turkey's Ceylan Holding was forced to withdraw from the project because of financial difficulties. In November 2000, Bulgaria issued new tenders for upgrading the Gorna Arda complex and has announced that state electricity utility Natsionalna Elektricheska Kompania (NEK) will now assume Ceylan's 50-percent stake in the

project [***55***]. Construction on the three-dam, 170-megawatt cascade project in the Rhodope mountains in Bulgaria's southeast were delayed repeatedly after Ceylan agreed to a joint venture with NEK in November 1998.

NEK is now seeking a partner to help finance the $220 million Gorna Arda project. Italy's Enel expressed interest in joining the project, but only if it can include the three-dam, 270-megawatt Dolna Arda cascade (located downstream from the Gorna Arda cascade) in the joint venture [***56***]. Enel argues that Gorna Arda cannot produce enough electricity to justify the $220 million investment and would have to sell electricity at 15 cents per kilowatthour to be profitable. In combination with Dolna Arda, however, the cost would fall to 8 cents per kilowatthour. Once construction begins, it is estimated that Gorna Arda would be completed within 6 years.

Plans to privatize several of Bulgaria's hydroelectric projects have not run smoothly. In 2000, the country's Privatization Agency (PA) had to ask bidders to resubmit their bids after senior politicians accused bidding companies of corrupting the sale process [***57***]. The accusations were leveled against companies that had submitted bids for the Pirinska Bistrica and Sandanska Bistrica cascades, which are considered two of the most attractive hydroelectric facilities of the 22 hydroelectric power assets, all with less than 25 megawatts of capacity, being sold by the PA. By July 2000, the PA had sold six of the offerings, including the three-dam Sandanska Bistritsa cascade to the Czech Republic's Energo-Pro and the two-dam Pirinska Bistritsa cascade to Bulgaria's Pirin 2001 [***58***].

In Romania there are a number of hydroelectric projects that have not been completed but could substantially increase the country's installed electric capacity. The country has disclosed that there are at least 12 partially built hydroelectric projects in Romania that will require foreign investment to finance their completion. In 2000, the U.S. engineering company Harza and Romania's hydropower producer Hidroelectrica signed an agreement to complete and jointly operate one of the plants, the 54-megawatt (reduced from 155 megawatts after an optimization study conducted by Harza) Surduc-Nehoiasu hydroelectric plant on the Buzau River [***59***]. Construction on the $60 million project should be completed by 2004.

Macedonia's electric utility, Elektrostopanstvo Na Makedonija (ESM), is planning a project to rehabilitate six of its largest hydroelectric plants: Vrutok, Vrben, Raven, Spilje, Tikeves, and Globocica [***60***]. Most of the plants are more than 40 years old, and their continued operation is considered vital for ESM. The six plants generated 92 percent of Macedonia's hydroelectricity supply in 1999. The total value of the project is estimated at $52 million, and it is slated for completion in 2004 (although it is already running 6 months behind schedule). In addition to reconstructing turbines, generators, and transmission facilities, replacing turbine circuits, and repairing transformers, total generating capacity is to be increased by 31 megawatts. Loans from the World Bank and the Swiss government, along with a grant worth $0.66 million from Japan and $12.1 million from ESM's own funds, will be used to complete the project.

There are also plans in Macedonia to develop the Chebren hydroelectric dam on the Crna River. Originally, the project was supposed to consist of two cascade dams, Skocivir and Galiste, along with the Chebren dam, which was to work with the Tikves hydroelectric plant to form the Crna system [***61***]. However, experts determined that the scheme would be unprofitable in that form. The government is now negotiating with an Austrian consortium led by Alpine and including Verbundplan and VA Tech Elin for a scaled-down version of the project in which only the Chebren accumulation would be constructed, thereby allowing the project to return a profit. If an agreement is reached, the project could be completed within 5 years.

There are plans to rehabilitate the 2,100-megawatt Iron Gates 1 hydroelectric plant, and Serbian utility EPS announced a tender to appoint a partner in the effort in June 2000 [***62***]. The plant is jointly owned and operated by Romania and Serbia, which plans to restore its half of the 12 turbine generators on the project. The upgrade will increase the installed capacity of each of the turbines by 15 megawatts (increasing total output by 10 percent). The project will cost an estimated $100 million and will be undertaken between 2001 and 2008. The Romanians are in the midst of restoring and upgrading their 6 generators at the plant.

Slovenia is also working to upgrade its hydroelectric facilities. Slovenian Dravska Elektrarne (DEM) is in the process of upgrading the Vuhred and Ozbalt hydroelectric plants [***63***]. This will be the second set of hydroelectric repairs and upgrades since DEM began the program in 1993. The first stage, which is nearly complete, involved raising the installed capacity of the Mariborski Otok, Dravograd, and Vuzenica hydro projects by a combined 34 megawatts. Installed capacity at Vuhred and Ozbalt will be increased by 31 and 39 megawatts, respectively.

There are only a few nonhydroelectric renewable projects underway in Eastern Europe. The World Bank is providing a $38.2 million loan for a geothermal district heating project in Poland as part of a $96.7 million plan to reduce air pollution in the country's southern Podhale Valley [***64***]. The project represents one of Eastern Europe's largest renewable energy projects, and it is one of the largest geothermal energy developments for district heating worldwide. The plant will be located in the

industrial town, Nowy Targ. Total installed heat generating capacity is projected to be 135 megawatts, with 38 to 43 megawatts supplied from the geothermal source and the rest supplied from gas-fired absorption heat pumps and gas-fired peaking plants.

Wind power has also begun making some limited progress in the EE/FSU. The Japanese government has granted a 40-year loan for $10 million to increase wind power by up to 10 megawatts in western Georgia and has promised an additional $50 million for constructing additional wind projects in Kutaisi [***65***]. Latvia's government has approved the construction of 11 wind farms in the country's western Liepaja region, each with a capacity of 1.8 megawatts [***66***], over the next 2 years. However, the state utility company, Latvenergo, has argued that the wind generators are too expensive, costing the company more than $4 million in subsidy tariffs to wind generators—which is passed on to consumers. Latvia has already approved construction of 18 wind farms, but so far only one (in Venspils) has been built.

Among the Eastern European countries, Poland's Wind Power Plants Joint-Stock Company announced that it would construct a 4.5-megawatt wind power project in Postomino [***67***]. Croatia's first wind project is slated to be built off the Stupisce peninsula near Komize on Vis Island [***68***]. Construction on the 6-megawatt, $7.8 million project is scheduled to begin once the Croatian utility, HEP, has repaired transmission lines on Vis. The project is part of the Program of Development of Renewable Energy Sources (PRORES) conceived by the Zagreb-based Energy Institute Hrvoje Pozar and endorsed by the government.

Developing Asia

Developing Asia is one of the only regions in the world that has plans to continue the development of large-scale hydroelectric projects over the *IEO2001* projection period, and the projected growth rates for renewables in the region are among the highest in the forecast. In developing Asia, hydroelectric and other renewable energy resources are expected to increase by 4.0 percent per year between 1999 and 2020. For China alone, 5.1-percent annual growth in renewable energy use is projected. China, India, Vietnam, Laos, and Malaysia, among other countries in developing Asia have extensive plans to expand their hydropower resources, and all have plans to use large-scale hydroelectric projects to achieve their goals.

China

China's plans for expanding its electricity capacity through large-scale hydropower projects are progressing, but international concern remains in the forefront of some of the more controversial plans. Construction of the mammoth Three Gorges Dam project, which—at 18,200 megawatts—is the world's largest hydroelectric project under construction, continued in 2000. In addition, plans are now under consideration to install a hydroelectric project in the Himalayas that would produce two times the output of Three Gorges. The proposed project is doubly controversial in that a report in London's *Sunday Telegraph* stated that there are plans to blast a tunnel through the Himalayas and to divert waters from the Yarlung Zangbo River (the upper reaches of the Brahmaputra), which flow to India and Bangladesh [***69***].

The Three Gorges project remains controversial, with many charges of corruption and problems in the program to relocate the estimated 1.13 million people from the area that will be flooded to create the 370-mile reservoir that will serve the dam. Dam officials have said they have relocated 253,200 people thus far [***70***]. Nevertheless, work on the project has continued, for the most part, on schedule. Construction of the estimated $30 billion project is occurring in two phases. Phase I began in October 1997 and will be completed with the installation of 14 700-megawatt turbines and generators in 2006. In phase II, another 12 700-megawatt turbines will be installed. The project is expected to be wholly operational in 2009.

There is concern that electricity production from Three Gorges will far exceed demand. The 3,300-megawatt Ertan dam became operational in 1998, but in 1999 the Ertan Hydropower Development Corporation was able to sell only about 60 percent of the dam's electricity output [***71***]. The situation was exacerbated by a decision from Chongqing to take a much smaller share of power than originally agreed. Chongqing had agreed to purchase 31 percent of Ertan's output but now is accepting only 14 percent, because electricity demand growth in the municipality has not kept pace with original expectations. Ertan lost some $120 million in 1999.

As a result of the surplus electricity supply available to Chongqing and other parts of central and western China, the government has revised plans for the electricity supplies from Three Gorges Dam. Originally, the project was supposed to transmit 12,000 megawatts of the capacity to central China, 4,200 megawatts to eastern China, and 2,000 megawatts to western Chongqing. Now, however, there are plans to send 3,000 megawatts to the southern province of Guangdong and to direct another 1,000 megawatts, originally slated to go to the central provinces of Hubei and Jiangxi, to the south.

Despite the present electricity surplus, the Chinese government has plans to increase the country's hydroelectric capacity even further. In 2000, the government released its latest plans for future development, stating that it expected installed hydroelectric capacity to reach 125,000 megawatts by 2010 [***72***]. China's goal is to

develop between 80,000 and 100,000 megawatts of additional hydroelectric capacity over the next two decades [***73***]. The country actually expects to export electricity over the next 20 years and has already agreed to ship 1,500 megawatts of power from the Jinghong Hydropower project to Thailand beginning in 2005, when the project is scheduled to be operational [***74***].

There are plans to expand micro-hydroelectricity in China, as well as plans to bring other renewable energy sources, such as wind and solar to the rural parts of the country. China has plans to deliver hundreds of small hydroelectric power stations to rural parts of the country where an estimated 75 million people do not have access to the national electricity grid [***75***]. The plan is to install the small hydroelectric systems to provide power in 600 rural counties by 2001, to be expanded by another 400 between 2001 and 2005 and another 400 between 2005 and 2010. China has already invested some $1.6 billion to add 1,000 megawatts of rural electric capacity each year since 1993.

The Chinese government would like to expand the amount of so-called "new" renewable energy sources and has set a target that 2 percent of the country's energy demand will be met by nonhydroelectric renewables by 2015 [***76***]. To help China meet its goal, the World Bank's Global Environmental Fund (GEF) approved a $12 million grant to install 98 megawatts of wind power in Dabancheng, Fujin, and Xiwaizi. The grant is part of a $98 million GEF project that is designed to help China diversify its energy resources and reduce its reliance on coal. At present China has only about 265 megawatts of installed wind capacity, out of a total 254,000 megawatts of installed generating capacity. Another $35.7 million GEF project co-financed with $372 million from World Bank funds would install 190 megawatts of wind power at five sites and supply about 200,000 photovoltaic (PV) and PV / wind hybrid[19] systems to households and institutions in remote areas of four northwestern Chinese provinces [***77***]. The project is scheduled for completion in 2002. The PV component is well underway, but the wind farm feasibility studies have not yet started, and that portion of the project is running behind schedule.

India

The development of renewable energy resources in India has been somewhat erratic over the past decade. The country was among the world's leaders in installing wind power in the early and mid-1990s, but by the late 1990s and into 2000 the number of new wind projects declined sharply with the end of many government incentives for the installations. Hydroelectricity, on the other hand, seems to have picked up some momentum in the last year. Hydropower accounts for about one-quarter of India's total installed electricity capacity. At present there are more than 695 dams under construction in India—for purposes of irrigation, electricity generation, and other uses [***78***].

Large-scale dam developers enjoyed a number of successes in India in 2000. In October, India's Supreme Court dismissed a petition filed by the Narmada Bachao Andolan (NBA) movement to stop completion of the 1,450-megawatt Sardar Sarovar dam project on the Narmada River [***79***]. The NBA had filed the suit, which resulted in a halt to work on the project in 1995. NBA argued that the dam developers had not made adequate plans for relocating hundreds of thousands of people who would be displaced by the project. The court did rule that the dam may only be constructed to a height of 295 feet, although developers had planned for a height of 453 feet. For every 16-foot height addition beyond the 295 feet, the developers will be required to obtain additional planning permission, including the approval of the environmental subgroup of the environment and forests ministry. Construction on the project was restarted at the end of October. When completed, Sardar Sarovar will provide power to Madhya Pradesh and will offer irrigation and food production benefits to Gujarat, Rajasthan, and other arid areas along the north and south banks of the Narmada River, some 600 miles south of New Delhi. The project does not have any fiscal support outside the country; the World Bank and Japanese government withdrew their support in the early 1990s.

In 2000, construction resumed on India's Kol Dam in Himachal Pradesh state, another hydropower project that had been delayed for a number of years [***80***]. This 800-megawatt hydroelectric project, in contrast to the Narmada scheme, was delayed because the state was unable to secure the funds to begin construction rather than for environmental reasons. Efforts to attract private-sector investment in 1995 resulted in only one bid during an international tender, and the project was withdrawn. Instead, the Himachal government asked the National Thermal Power Corporation to build, own, and operate the Kol Dam project.

The northern Indian state of Jammu and Kashmir has signed an agreement with the National Hydropower Corporation (NHPC) that will result in an additional 2,778 megawatts of hydroelectric capacity [***81***]. The agreement involves seven projects that NHPC will construct on a build, own, operate, and transfer (BOOT) arrangement. The new projects are the 1,000-megawatt Pukhal Dul, 1,000-megawatt Busrar, 330-megawatt Kishan Ganga, 280-megawatt Uri-II, 120-megawatt

[19] Hybrid systems work with a renewable energy source that is backed up by a nonrenewable component. For example, a photovoltaic-diesel system would have a diesel generator that would start up when there was not sufficient sunlight to operate the photovoltaic component.

Sewa II, 30-megawatt Nimo Bazgo, and 18-megawatt Chaktak projects. They are estimated to cost $3.6 billion and should become operational within 7 years. Further, Jammu and Kashmir Power Development Corporation, a state-owned company, plans to pursue two additional hydro projects in the state, the 450-megawatt Baglihar and 600-megawatt Sawalkote dam schemes; however, financing for the two dams has not yet been secured.

West Bengal has also decided to try to attract private investment to develop the state's hydroelectric resources. The state relies heavily on thermal-generated electricity and, at present, has a thermal-hydro ratio of 97:3 [***82***]. In an effort to increase the diversity of the energy mix, West Bengal is now in the process of installing a 900-megawatt pumped storage project financed, in part, by the Japanese Bank for International Cooperation. The NHCP has agreed to participate in the third and fourth stages of the Teesta low dam hydroelectric project in the state, adding 100 megawatts and 132 megawatts of installed capacity to the project [***83***]. The project is scheduled to be completed by the end of 2005.

There are also a number of small hydroelectric projects planned or under construction in India. The country's Central Electricity Authority approved an 80-megawatt hydroelectric project in the northeast state of Mizoram in 2000 [***84***]. The $111 million project is scheduled for completion by 2007 and will include a 204-foot-high dam across the Bairabi River, improving navigation from the dam to Aizwal and Assam communities through a 112-mile waterway. Himachal Pradesh state signed power purchase agreements to develop 12 mini-hydro projects with a combined installed capacity of 26.3 megawatts in April 2000 and, in July 2000, signed agreements for the development of eight additional hydroelectric projects with a combined installed capacity of 254 megawatts [***85***].

Other Developing Asia

There are plans to expand the hydroelectric resources in several developing Asian countries over the next several years. Plans for expanding hydroelectric potential in Vietnam, Malaysia, Laos, and Nepal, to name a few, help to advance the *IEO2001* reference case projections for renewable energy consumption in this region. There are also a number of small, off-grid renewable projects that are being sponsored to help provide rural populations in the region with access to electricity.

In Malaysia, plans for the controversial Bakun hydroelectric project took another turn this year. The government announced in late 1997 that it planned to scale the project down from 2,500 megawatts to 500 megawatts because of the drop in electricity demand during the southeast Asian economic recession. In mid-2000, however, the government reviewed its decision and announced that it would consider restoring the project to its original size [***86***]. Critics argue that the dam would displace more than 9,000 indigenous people and would flood 70,000 hectares of rain forest [***87***]. The $13.5 billion project is being constructed by the Sarawak Hydroelectric Corporation. Three diversion tunnels already under construction should be completed before April 2001, and Bakun could be completed within 5 years [***88***]. Once the diversion tunnels are completed, work will begin on a 295-foot-high dam when the government agrees on the capacity.

In Pakistan, construction on the 1,450 megawatt, $2.2 billion Ghazi Barotha hydroelectric project is scheduled for completion in 2002. The project is being built at the confluence of the Indus and Haro Rivers in the Northwest Frontier Province. State-run Water and Power Development Authority announced it would be more than 62 percent complete in 2000 [***89***]. Although Gazi Barotha is a large-scale scheme, it is not expected to result in wide displacement of the local population. Only 115 households are to be displaced by construction, and three model villages in the vicinity of the original dwellings have already been created. The first of five 290-megawatt units is slated to become operational in August 2002, with the remaining units coming on line by the end of that year. The World Bank, Bank of Germany, European Investment Bank, and Islamic Development Bank are all helping to finance the project.

Nepal has particularly rich hydroelectric resources, with an estimated potential to develop some 83,000 megawatts of hydropower capacity. The resources remain largely untapped, however, because of the country's difficult geography and poor tax base (only an estimated 15 percent of the population of 23 million have access to electricity). In 1999, Nepal announced that it expected the country's hydroelectric capacity to double by the end of 2001, easing the acute power shortages in the country. Installed hydroelectric capacity is scheduled to increase from 289 megawatts to 570 megawatts by September 2001, as a number of power plants are commissioned. The country is heavily dependent on India for trade and hopes to develop its hydroelectricity so that it can also export excess electricity supplies and reduce its trade deficit with India [***90***]. The Bhote Koshi power station and the Kali Gandaki project are expected to begin operating in the first half of 2001, along with some other, larger projects, and the country plans to sell some 150 megawatts of excess hydroelectric power to India (up from the present 50 megawatts) during Nepal's rainy season.

There are plans to revive the Arun III run-of-river hydroelectric project in Nepal's Arun Valley. The U.S. company Eurorient Investment Group received approval from the Nepal government to construct the

402-megawatt project [***91***]. The project was originally backed by the World Bank in the mid-1990s, but the plan was eventually dropped because of the financial burdens it would have imposed on the country. Environmental groups had also criticized the project as potentially damaging to the region's forests and disruptive to the 155 households that would have been displaced by the scheme. In 1999, the Nepalese government invited the private sector to bid on the project.

Nepal's largest private hydroelectric project began generating electricity in July 2000 [***92***]. The 60-megawatt Khimti plant is located on the Khimti Khola River at Kirne, about 105 miles northeast of Kathmandu. It cost $140 million to construct and was developed by Himal Power Limited in conjunction with Norway's Statkraft.

In Laos, hydroelectric capacity is being developed as an export commodity. In mid-2000, Thailand signed a Memorandum of Understanding with Laos for a 25-year power purchase agreement to take electricity from Nam Theun 2 [***93***]. When the final agreement is signed, construction on the 920-megawatt power project in central Laos will begin. The project is expected to cost $1 billion to complete, and delivery of the Thai electricity is expected to begin in December 2006.

Vietnam is planning several hydroelectric projects to help meet growing electricity demand [***94***]. In 2000, Electricity of Vietnam submitted a feasibility study to the government for the Rao Quan hydroelectric power project, which would generate 260 million kilowatthours of power per year and whose reservoir would irrigate 12,281 hectares of rice paddy and 1,600 hectares of cereal crops. The proposed project would also help regulate the flow of the Thach Han River in Quang Tri and provide a more reliable water supply for the local population. The project would cost an estimated $140 million and would be located in the Rao Quan Valley, about 40 miles from Dong Ha and 16 miles from the Laos border.

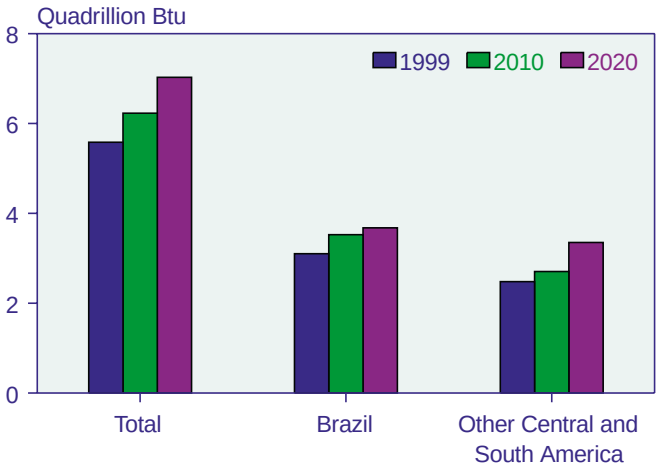
The World Bank's International Development Association approved a $150 million credit to Vietnam in 2000 to help extend electricity to about 450,000 households throughout the country, with an emphasis on households in northern Vietnam where the poorest rice farmers and cashew nut and coffee producers live [***95***]. Mini-hydro systems are to be used to supply electricity in the more remote parts of the country, but approval for that part of the project is not scheduled until 2001.

In the Philippines, the government is trying to encourage the development of hydroelectricity and geothermal electricity resources, as well as renewable generation using solar, photovoltaic, hybrids, wind, and biomass [***96***]. The government is attempting to reduce its dependence on energy imports, and the development of renewables is an important part of its scheme to provide 100 percent of the population with access to electricity. Renewable energy sources are seen as an important way in which to supply electricity to rural and remote areas that cannot be reached by the national electricity grid. The government would like to provide electricity access to some 9,000 remote villages before 2002, and there are plans to use wind, solar, or mini-hydro in about half of them [***97***]. The government plans to invest $330 million overall for the project. To date, more than 1,500 villages have been electrified.

Central and South America

Hydroelectricity remains an important source of electricity generation in Central and South America, and many countries in the region rely heavily on hydropower for their electricity supplies. In 1998, hydropower accounted for 91 percent of Brazil's total electricity generation [***98***]. Smaller Central and South American economies also depend on hydroelectricity. Paraguay generates virtually all of its electricity from hydropower, Chile about half, and oil-rich Venezuela almost three-quarters. The picture is expected to change over the projection period, however, as countries concerned about the effects of potential drought on the electricity supply attempt to diversify their electricity fuel mix, particularly by developing natural-gas-fired capacity. Hydroelectricity and other renewable resources are expected to expand by 0.6 percent per year in Brazil between 1999 and 2020 in the *IEO2001* reference case projection, and by 1.4 percent per year in the region as a whole (Figure 75).

Figure 75. Renewable Energy Consumption in Central and South America, 1999, 2010, and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2010 and 2020:** EIA, World Energy Projection System (2001).

Brazil

There are only modest plans to expand hydroelectric resources in Brazil. In 2000, plans to auction off concession licenses to build and operate 11 new hydroelectric projects were announced [***99***]. The plants will be constructed in Brazilian states Rio Grande do Sul, Minas Gerais, and Rio de Janeiro. Their combined capacity is estimated at 1,396 megawatts, and they are expected to bring electricity to 8.6 million people. At present, total installed capacity in Brazil is approximately 65,000 megawatts, in a country of about 164 million people [***100***]. The cost of constructing the plants has been estimated at close to $4.1 billion, and they are scheduled to be completed by 2004. In addition, there are plans to offer concession licenses for another 17 hydroelectric plants, with capacities between 50 and 1,200 megawatts each, sometime during 2001.

The Inter-American Development Bank approved $160.2 million in loans to support the development, construction, and maintenance of the 450-megawatt Cana Brava hydroelectric project on Brazil's Tocantins River, about 200 miles north of Brasilia in Goias State, between the towns of Calvancanti and Minacu [***101***]. The project, which is being constructed by Belgium's Tractabel, has been the object of criticism, particularly by the Brazilian environmental group, Movimento dos Atingidos por Barragens (or the Brazilian Movement of Dam-Affected People—MAB) because of concern about how Tractabel is handling the relocation of 200 families that will be displaced by Cana Brava [***102***]. MAB had requested that the Inter-American Development Bank not finance the project.

The 156-megawatt Itiquira Energetica SA hydroelectric project in Brazil's southwestern Mato Grasso state is also currently under construction. The project is being developed by U.S. NRG Energy and Sweden's government-owned utility, Vattenfall AB. Itiquira is about 30 percent complete and is expected to begin operating in 2002 [***103***].

The Brazilian government has pledged to increase the number of nonhydroelectric renewable energy projects in the country in an effort to provide electricity to people whom the national electricity grid cannot reach. In 1999, the government announced that an investment of some $25 billion would be required to bring electricity to the 20 million people without access to electricity in Brazil [***104***]. In December 1999, the Multilateral Investment Fund announced a $4.45 million grant to Brazil to help develop private-sector renewable energy pilot projects that show promise in delivering electricity to isolated parts of Brazil under the National Program for Energy Development of States and Municipalities (PRODEEM) [***105***]. The Japanese Special Fund, administered by the Inter-American Development Bank, also provided the PRODEEM program with an $898,950 grant in September 1999 for improving the management and effectiveness of the program [***106***].

Other Central and South America

Hydroelectricity and other renewable energy sources are also being expanded in other parts of Central and South America. In November 2000, Peru's 149-megawatt Chimay and the 42-megawatt Yanango hydroelectric projects that form the hydro complex known as Chinango became fully operational [***107***]. The complex cost $200 million to complete and marks the single largest private sector investment in a Peruvian energy for 30 years. The complex is owned by Enersis.

In Colombia, the government has been trying to press forward with energy privatization plans, but attacks from the communist guerrilla Colombian Armed Revolutionary Forces (FARC) movement on various energy projects have forced the government to delay its plans. Many of the attacks have been directed at pipeline projects, but in 2000 the FARC successfully attacked the 74-megawatt Bajo Anchicaya hydroelectric power plant in western Colombia and caused a blackout for nearly half of Buenaventura, Colombia's principal port [***108***]. The cost of direct losses resulting from the attack are estimated at more than $2 million; indirect losses were estimated at considerably more because port and commercial operations in Buenaventura were stopped for several days as a result of the blackout. The government was fortunate that only the 74-megawatt plant was disabled, rather than the entire 340-megawatt Anchicaya hydroelectric complex. The plant is located about 6 miles from its dam.

In Bolivia, the U.S. Initiative on Joint Implementation (USIJI) approved construction on the 83.5-megawatt Taquesi run-of-river hydroelectric project in July 2000 [***109***]. The Taquesi project will consist of two run-of-river developments and the rehabilitation of an existing 850-kilowatt project on the Taquesi and Unduavi Rivers. Construction is scheduled for completion in 2001. The project qualifies under USIJI as a carbon dioxide reduction project, and the project developer Hidroelectrica Boliviana SA will be able to offer carbon trading credits under an international greenhouse gas reduction program. Taquesi represents one of the largest projects ever approved by USIJI and is expected to reduce carbon dioxide emissions by approximately 10 million metric tons over the facility's 36-year life.

In Chile, work on Endesa's Ralco hydroelectric project on the upper part of the BioBio River was halted in February 2000 by several lawsuits [***110***]. Ralco would be the largest hydroelectric project in Chile at 570 megawatts, and if it is completed it will add 18 percent to the capacity of Chile's central electricity grid. The project is

scheduled to become operational in 2003. In January 2000, former Chilean President Frei granted the concession for construction, but the comptroller-general objected, causing construction to stop. The dam has been controversial since its construction was first announced in 1994. It will flood almost 8,600 acres and force the relocation of the indigenous Pehuenche residents.

There is some urgency associated with increasing the installed electricity capacity in Chile. Electricity demand in the country is expanding by about 8 percent per year. In 1998, three new gas-fired plants added 1,000 megawatts to Chile's central grid, increasing its capacity by a fifth, but no other plants are due to come on line until 2003, when Ralco is scheduled for completion [***111***]. While there are plans to expand the gas-fired capacity in the long run, it has been reported that heavy worldwide demand for combined-cycle plants means that none are available to Chile until at least 2003.

There are also some efforts to increase the penetration of nonhydroelectric renewables in Chile. By some estimates, Chile may have geothermal generating capacity approaching 16,000 megawatts, and the government hopes that geothermal energy will become a significant part of the country's national electricity system over the next 10 to 15 years [***112***]. Unfortunately, geothermal is not, at present, competitive with hydroelectricity. Chile's state oil company, Enap, has estimated that geothermal power plants will cost $650 to $1,500 per kilowatt to install, compared with $1,000 per kilowatt for hydroelectric and $300 per kilowatt for gas-fired plants [***113***]. Geothermal pilot projects are being developed for heating greenhouses, drying fruit, and fish farming.

Wind power in Chile has only begun to be developed, despite favorable wind resources. In October 2000, a wind-diesel hybrid village power project on the island, Isla Tac, Chiloe, began operation [***114***]. The project was funded by the U.S. Agency for International Development and Chile's Comision Nacional de Energma. The 15-kilowatt project works with a 12-kilowatt backup diesel generator. The system is to be used by a rural community of 350 people.

In Argentina—as in Brazil—there is a concerted effort to supply electricity to some of the more remote, isolated population. Although 95 percent of the total Argentine population has access to electricity, an estimated 30 percent of the rural population lacks electricity and other basic infrastructure [***115***]. In 1995, the Argentine Secretaria de Energia created the Programa de Abastecimiento Eléctrico a la Población Rural de Argentina (PAEPRA) to develop off-grid electricity to residents in rural locations and to provincial public services such as schools, police stations, and health centers. The goal of PAEPRA is to ensure that 1.4 million people (about 314,000 households) and 6,000 public services are provided with electricity.

A component of the PAEPRA, the Proyecto de Energia Renovable en el Mercado Eléctrico Rural (PERMER), is being implemented jointly by the Argentine government and the World Bank in eight provinces. PERMER will provide electricity for lighting, radio, and television to about 70,000 rural households and 1,100 provincial public service institutions through private developers, using mainly renewable energy systems. The project is to be completed before 2006. The estimated total cost of PERMER is $120.5 million, which will be financed by the World Bank ($30 million loan), Global Environment Facility ($10 million grant), the Electricity Investment Development Fund ($26.5 million subsidy to customers), the energy developers ($44 million), and the consumers ($10 million).

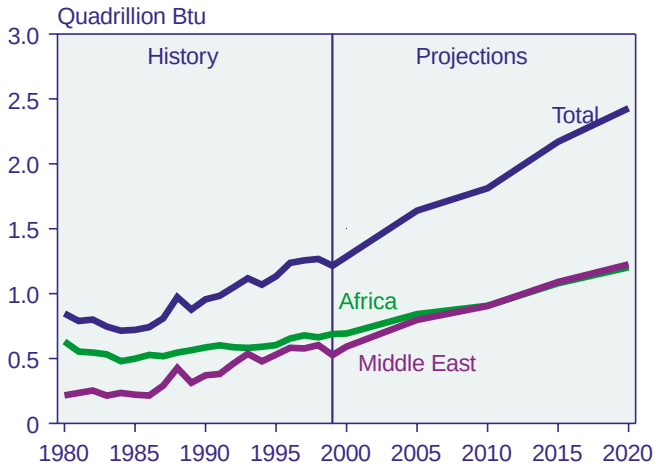
Africa and the Middle East

In Africa and the Middle East, hydroelectricity and other renewable energy sources have not been widely established, except in a few countries. In the Middle East, only Turkey and Iran have developed their hydroelectric resources to any extent. Hydroelectricity accounts for 45 percent of Turkey's total installed capacity (10,000 megawatts out of 23,000 megawatts) and for 7 percent of Iran's total (2,000 megawatts out of 30,000 megawatts) [***116***]. In Africa, Egypt and Congo (Kinshasa) have the largest volumes of hydroelectric capacity, but other countries, including Ivory Coast, Kenya, and Zimbabwe, are almost entirely dependent on hydropower for their electricity. (Many countries in Africa are generally lacking in the development of electricity infrastructure.) Renewable energy use in Africa and the Middle East is projected to rise from 1.2 quadrillion Btu in 1999 to 2.4 quadrillion Btu in 2020 (Figure 76).

Nonhydroelectric renewable energy sources have not been developed to a large extent in the Africa/Middle East region and account for almost none of the region's installed electricity capacity. There are some efforts to bring small, off-grid projects to isolated parts of Africa and the Middle East to provide access to electricity to dispersed rural populations.

The most important wind energy project developments in Africa have taken place in Egypt and Morocco [***117***]. Morocco has set a target of electrifying the rural parts of the country by 2010 (currently only 15 percent of the rural population has access to electricity) [***118***]. The country intends to invest some $3.7 billion in energy projects through 2003, a portion of which will go toward rural electrification projects, including wind projects. In late 2000, a $56 million, 50-megawatt wind farm went into operation at Koudia el Beida near the Straits of

Figure 76. Renewable Energy Consumption in Africa and the Middle East, 1980-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

Gibraltar. In August 2000, the state-owned Office National de l'Electricité issued a tender for the construction of 200 megawatts of wind capacity in two wind farms to be located in the northern and southern area of Tangiers and Tarfaya [***119***]. The total cost of construction for the two wind farms has been estimated at $200 million.

Egypt is planning to expand its use of nonhydroelectric renewables over the next several years. The country plans to build a 30-megawatt solar power plant at Kureimat funded in part by the World Bank's GEF, which will pay the difference between constructing the solar plant and a comparable-sized thermal unit. In addition, the Netherlands is funding a 60-megawatt wind project in the Suez Canal area.

South Africa and Uganda have plans to build substantial hydroelectric projects during the forecast period. U.S. independent power producer AES is expected to construct the $520 million, 250-megawatt Bujagali dam on the Nile in Uganda [***120***]. The project is scheduled to become operational in 2005 and will increase Uganda's existing power supply by 40 percent [***121***]. Construction of South Africa's Lesotho Highlands Water Project, which includes six dams on the Senqu River, represents Africa's largest infrastructure project. The project is the subject of international criticism because of the displacement of more than 30,000 people. In 1999, Lesotho came under further criticism from the World Bank—which has provided funds for the hydro project—for corruption when European, Canadian, and South African contractors involved with the $8 billion project were charged with paying bribes to the former chief executive of the Lesotho Highlands Development Authority [***122***].

In the Middle East, Turkey has the most ambitious expansion plans for hydroelectricity. Turkey continued, despite strong international criticism, to pursue its plans to construct the 1,200-megawatt Ilisu hydroelectric project [***123***]. Ilisu is part of the Southeastern Anatolian Water Project, known as GAP. When completed, GAP would consist of 22 dams and 19 hydroelectric plants on the Euphrates and Tigris Rivers. The project was conceived in the late 1970s and, if taken to full completion, will cost in excess of $32 billion. Ilisu alone will cost an estimated $2 billion to construct and will be the fifth largest dam in the world. Critics cite the destruction of countless architectural treasures as the reservoir that is required to support the dam project will flood the ancient Roman town of Zeugma, among others, and will cause the displacement of between 25,000 and 75,000 people [***124***].

There is mounting pressure on companies and export credit agencies to withdraw support from the Ilisu project. The Swedish company, Skanska, which had held a 24-percent stake in the project, withdrew in November citing concerns about the project's failure to meet international standards [***125***]. If the project remains on schedule, the dam will be completed by 2008 [***126***].

There are efforts to introduce wind power in Turkey as well, and the country plans to begin construction on its first large-scale wind project at the end of 2000. The installation of 120 megawatts of wind capacity is supposed to be the first phase of a 350-megawatt wind power development scheme. The Turkish government has scheduled the release of another renewable energy tender offer in April 2001 [***127***]. The first part of the project will be a 30-megawatt wind farm on the cliffs of the Dardanelles straits, west of Istanbul. Two other projects to be located in the Cesme area near the city of Ismir will have a combined installed capacity of 90 megawatts. Construction of the three projects is to be completed by the end of 2001.

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